SURVEYS OF CARIBOU, MOOSE, AND WOLVES IN NORTHERN BRITISH COLUMBIA IN 1978-79 and 1979-80

- a summary of results -

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PREFACE

This report was prepared as a working document for use by Ministry of Environment staff. It is in the final stages of technical review, and a final document is slated for publication.

Because of the considerable interest in wolves and ungulates in northern B.C., we are making this draft available to the public as background information. Readers are reminded that while useful as a planning/working document, it is not in the polished form planned for publication.

Fish and Wildlife Branch
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SUMMARY

Twenty-five areas in northern British Columbia were surveyed for caribou, moose, and wolves during a two year period. The purpose was to collect information on the three species to help wildlife managers assess the impact of wolf predation on ungulate populations in the area. All surveys were made by Ministry of Environment staff from helicopters or fixed-wing aircraft. A total of 4,789 caribou were counted in 1978-79, in nineteen survey units. The estimated calf crops (number of calves counted/total number of caribou counted) ranged from 8% to 36%. In 1979-80, 4,686 caribou were counted on nineteen units, and calf crops varied from 6% to 21%. Fourteen of the units surveyed were the same in both years; five were different units. For moose, surveys were made in five areas in 1978-79, and four areas in 1979-80. In total 1,175 moose were counted. Calf proportions ranged from 9% to 28% over the two years. Densities of moose were estimated at 0.23 to 1.33 moose/sq. km. A total of twelve areas were surveyed for wolves in 1978-79, and eleven areas in 1979-80. Estimated wolf densities ranged from 105 sq. km/wolf to 540 sq. km/wolf. Results of the surveys indicated that areas with higher proportions of calves in the caribou herds had lower densities of wolves than areas with low proportions of calves. These results support the suggestion that wolf predation can control caribou numbers when the wolves prey heavily on the young. The limited information obtained for moose suggests there is a similar relationship between moose numbers and wolf predation, but additional surveys are needed to provide better documentation.

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"Succinctly .... if the habitat is alright the animals must be doing well - such is not the case."

Bergerud, (1978).

INTRODUCTION

The purpose of this report is to present the results of a two year inventory program of caribou*, moose, and wolves in the northern half of British Columbia. This program arose from a growing concern by the public and the Fish and Wildlife Branch over declining numbers of caribou and moose since the early 1970's, and the apparent role of wolf predation in causing these declines.

In 1978, special funds were allocated to identify those aspects of the population dynamics of caribou, moose, and wolves that might reveal means of reversing the apparent downward trend in ungulate numbers. The aspects examined included annual recruitment for caribou, density and recruitment for moose, and density for wolves. A comparison of these population parameters between survey areas would help indicate the importance of wolf predation as a population regulator.

Predation, especially by wolves, was given particular scrutiny because several major reports highlighted the potential for predation to control ungulate numbers. In a survey of British Columbia's caribou herds, Bergerud (1978) suggested that their decline since the late 1960's resulted from predation and overhunting. In the fall of 1977 and the early part of 1978, he found some herds with calf crops ranging from 2% to 6%, well below the 10% necessary to replace the estimated annual natural mortality of adult caribou. Since the estimated pregnancy rate of 85% was typical for caribou, Bergerud suggested that these low calf crops resulted from heavy

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* Common and scientific names of animals and plants mentioned in the text are listed in Appendix A.

predation of newborns, especially by wolves. Preliminary field work in Spatsizi Plateau Wilderness Park supported this suggestion (Bergerud and Butler 1978).

Independent work by Haber (1977) and his associates (Haber et al. 1977) pointed to another concern in large mammal systems where both predation and hunting existed. Computer modelling of data collected in Alaska's Mount McKinley Park suggested that, with wolves as the principal predator, a predator-prey system could exist at several equilibria. Judging population trends by recruitment figures only could be misleading since populations with similar composition could increase or decrease, depending upon prey and predator densities. These workers also predicted that the shift from a high to low equilibria could be precipitated easily if densities decreased through outside disturbances, and that the system would remain at this low level unless disturbed by major events such as large scale migrations, excessively hard winters, or wolf control.

Ecological systems are complex, and caution is necessary in accepting simple explanations for observed changes in systems. Thus the importance of wolf predation in controlling ungulates must be tempered by consideration of other factors such as Mech and Karns (1977) found for wolves and white-tailed deer in Minnesota. Also models do contain assumptions, and the realism of Haber's model has been questioned by workers such as van Ballenberghe (1980).

Whether or not these "equilibria" hypotheses are disproved, one important consequence of recent research is that the type and intensity of information necessary to manage large predator-prey systems needs to be modified. Also, the interpretation of data must now consider the implications of multiple equilibria.

Many individuals worked on this progam and on this report. Most of the surveys were done by regional wildlife biologists and technicians. By region, these people are: Region 5: H. Mitchell and W. Prediger (both now deceased); Region 6: D. Hatler and K. Hodson; Region 7-Omineca: K. Child and K. Fujino; Region 7-Peace: J. Elliott and B. Webster. Others who helped in surveys were G. Hazelwood, C. Kissinger, W. Macgregor, and D. Eastman. Early drafts of the report were prepared by J. Elliot, D. Eastman, and M. Nation, and were reviewed by the above staff plus D. Hebert, R. Ritcey, and B. vanDrimmelen. Maps, figures, and the cover were designed and produced by Laura Friis. Drafts were typed by Lynda Adams, Ann Evans, and Louise Reid; the final report was typed by Lynne Foxall. The able assistance by pilots for both helicopter and fixed wing aircraft is also acknowledged.

Copies of flight reports and data summaries used to prepare this report are in files at the appropriate regional Fish and Wildlife, Ministry of Environment offices in Fort St. John, Prince George, Smithers, and Williams Lake. Also, copies of all data are filed in the Victoria office of the Fish and Wildlife Branch.

METHODS

SELECTION OF STUDY AREAS

Twenty-five areas were selected by regional personnel for inventory of caribou, moose, wolf, or combinations of these species. Some survey areas varied between years as determined by the availability of funds, vagaries of the weather, snow conditions, the location of target herds or packs, the addition and deletion of areas, and work priorities within each region.

Generally, boundaries of survey units followed conspicuous geographic features such as rivers, lakes, landforms, and heights of land; ecological boundaries such as changes in general vegetative cover, changes in ungulate or wolf sign; and cultural factors such as seismic lines, highways, railways, utility corridors, and boundaries of previous survey areas.

The sizes of these census areas were determined with a compensating polar planimeter (Keuffel and Esser Co., Model No. 62000) on 1:250,000 scale univeral transverse mercator maps of the National Topographic series. These estimates were for plane or map areas only, recorded to the nearest 10 sq. km.

SURVEY PROCEDURES

Surveys were conducted by government personnel experienced in conducting wildlife surveys. Survey techniques varied in response to differing field conditions and survey requirements. All surveys were aerial, mostly by helicopter

(Bell Jet Ranger, Hughes 500 and 500E, Hiller), excepting some fixed-wing flights in the Peace subregion.

For caribou, the primary intent was to estimate annual rec itment for the herds. Most search effort was concentrated in locations of known or expected caribou abundance within the larger, annual herd range. Total counts were attempted where feasible but, based on our experience in ungulate surveys, some animals were likely missed in counts. Most flights were done in October, the period of rutting aggregations; however, it was found more effective to observe some herds such as the Atlin, Liard Plateau and Toad River herds during late winter. In addition, logistic and general cost considerations led to two other caribou areas being examined in late winter, MacDonald-Racing and Gataga-Kechika. Calf caribou were distinguished from adults on the basis of size, while cows were separated from bulls on the basis of presence or absence of the vulva. Searching within designated areas was done systematically by linear transects or contours matched to the range of observability.

For moose, information was collected three ways. On the caribou survey units, moose were classified incidentally. These moose data contain biases resulting from sex- and age- related differences in moose distribution, e.g. bull moose tend to be found more frequently in the higher caribou wintering areas than in other moose winter ranges. On the moose survey units, the age and sex composition of the herds was estimated. Calves were distinguished on the basis of size. Where data were collected in early winter, yearlings were estimated by doubling the count of spike-antlered bulls, assuming that these were yearling moose, and that survival of males and females was equal during the first 18-20 months of life. Cows were

separated from bulls on the basis of white hair adjacent to the vulva, lighter brown noses, and the absence of antlers or antler scars.

In addition to classified counts, moose densities were estimated by stratified random block or quadrat surveys on four areas: Beatton-Blueberry, Cameron-Chowade, Level Mountain, and Horseranch Range. Each area was subdivided into high, medium, and low density strata based on previous information, habitat features, or reconnaissance flights prior to the surveys proper. The number of quadrats and their allocation to density strata was based on available funds, density class, logistics, size of strata, and anticipated variability within strata. On the Level Mountain area, 2.6 km^2 quadrats were used, with boundaries determined by compass bearings, flight velocity, and a stop watch relative to an identifiable corner. On the remaining three survey units, blocks were polygons whose boundaries were defined by recognizable landscape features such as gullies, ridges, streams. Plots averaged 0.6 km^2 on Horseranch, and 2.6 km^2 on Beatton-Blueberry and Cameron-Chowade. In all cases, sample plots were searched intensively by flying closely spaced, parallel transects, taking care to minimize double-counting.

Wolf surveys took two forms. On the Itcha and Ilgachuz Ranges and the Atlin area, wolf numbers were estimated on the basis of tracks and occasional sightings encountered during transects for caribou. For the other areas, all logical wolf travel routes such as stream courses, trails and ridges were followed. Where feasible, tracks were followed to determine pack travel routes, or actual animals in a few cases, thus assisting in delineating pack sizes, and ranges, and in avoiding recounts. Observers undertook frequent ground examinations of tracks to ascertain animal numbers. Other than the intensively searched Horseranch area,

few wolves were seen in relation to estimated totals.

ANALYSIS OF DATA

For caribou, recruitment estimates are expressed as proportions of the total number counted, provided the number classified is > 50 animals. Fall calf crops probably overestimate yearling recruitment by approximately 1-2%, the proportion lost over winter (Bergerud 1978).

For moose, recruitment was calculated in the same way as for caribou. For the four areas where density was estimated by stratified random sampling, standard statistical procedures were followed. These estimates were not corrected for biases.

For wolves, the densities were expressed as sq km/wolf or wolves/100 sq km.

RESULTS

SURVEY AREAS

During the two year program, 25 areas situated in the northern half of the province were surveyed (Fig. 1). Their selection was based on the following criteria: evidence for declining numbers of moose or caribou; concern for overharvest; estimated size of population; cost of surveying and availability of funds; and quantity and quality of existing data. Detailed locations, maps, and area boundaries are in Appendix B. The name, area, target species, and biogeoclimatic zones of the study areas are given in Table 1. Environmental features of these zones are described in Table 2.

EVALUATION OF DATA

Except for caribou surveys on the Atlin, Level Mountain, Mt. Edziza, Spatsizi, and Lawyer's Pass survey units, results for all other areas and species were based on single flights. Since herds and packs can vary over time in size and composition, the results from single counts must be regarded cautiously. Assessing the adequacy of survey data involves a high degree of judgement by the surveyors and the biologists using these data. This judgement is based on training and experience, and a careful assessment of the counting conditions and the consistency of survey data with other, independently collected information.

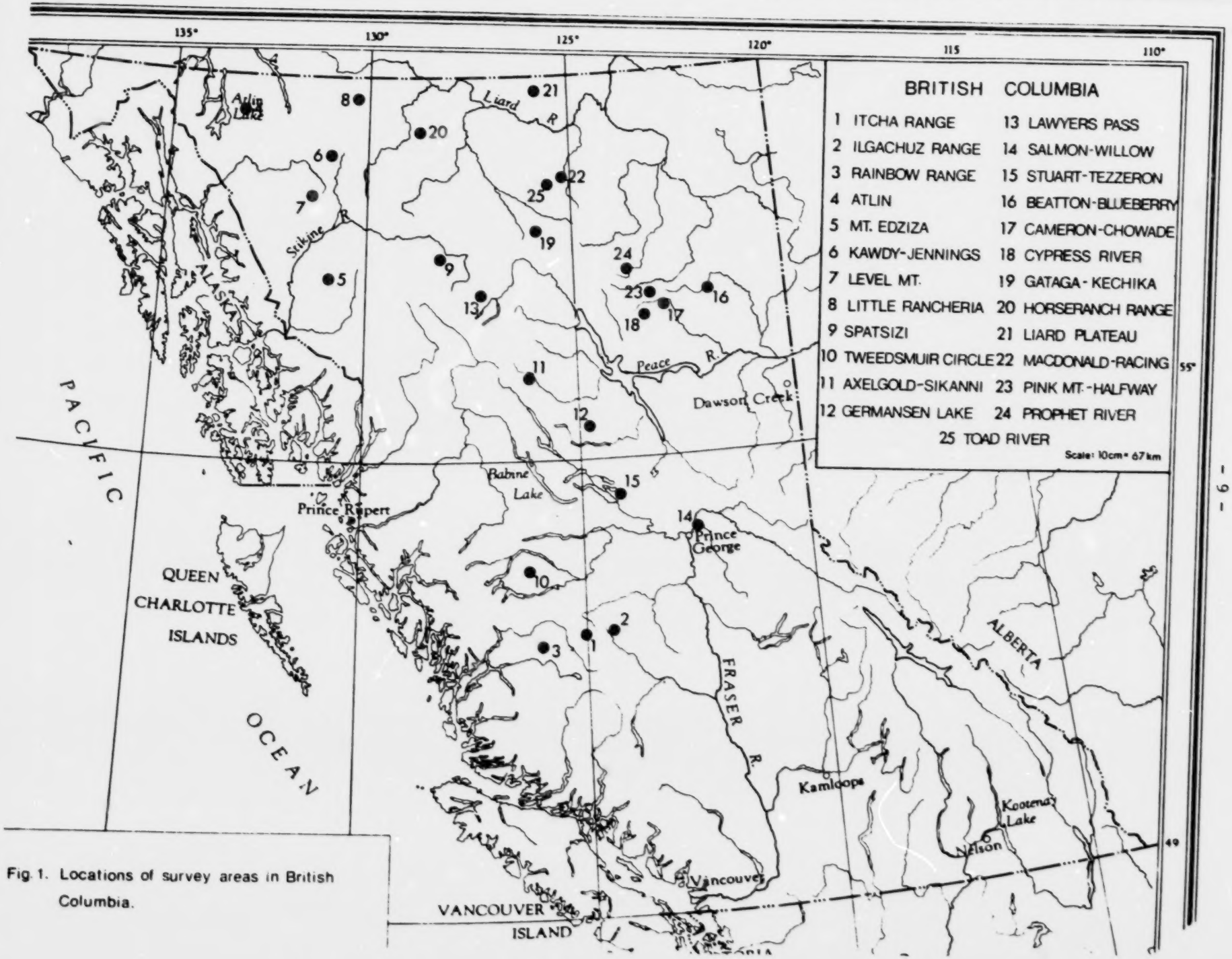


Fig. 1. Locations of survey areas in British Columbia.

Table 1. Names, target species, approximate area, year surveyed, and major biogeoclimatic zones of areas surveyed in the wolf/ungulate project, 1978-79 and 1979-80.

Region or subregion	Survey unit	Target species[1]	Biogeoclimatic zones[2]	Approximate area surveyed (km^2)
5 - Cariboo	Ilgachuz Range	C,W	AT, ESSF	2,340 (✓,✓)[3]
	Itcha Range	C,W	AT, ESSF	1,730 (✓,✓)
	Rainbow Range	C	AT, ESSF	1,770 (✓)
6 - Skeena	Atlin	C,W	AT, ESSF	1,770 (✓,✓)
	Kawdy-Jennings	C	AT, ESSF	1,310 (✓,✓)
	Level Mountain	C,M,W	AT, ESSF	4,560 (✓,✓)
	Little Rancheria	C	AT, ESSF	530 (✓)
	Mt. Edziza	C	AT, ESSF	1,400 (✓,✓)
	Spatsizi	C,W	AT, ESSF, BS	1,370 (✓,✓)
	Tweedsmuir Circle	C	AT, ESSF	4,300 (✓,✓)
7 - Omineca	Axelgold-Sikanni	C	AT, ESSF, SBS	1,010 (✓)
	Germansen Lake	C	AT, ESSF, SBS	1,330 (✓,✓)
	Lawyers Pass	C	AT, ESSF, SBS	1,995 (✓,✓)
	Salmon-Willow	M	SBS	2,350 (✓,✓)
	Stuart-Tezzeron	M	SBS	2,790 (✓,✓)
7 - Peace/Liard	Beatton-Blueberry	M	BS	4,480 (✓)
	Cameron-Chowade	M,W	AT, ESSF, BS	4,950 (✓,✓)
	Cypress River	C,W	at, essf, BS	570 (✓,✓)
	Gataga-Kechika	C,W	AT, ESSF, BS	5,610 (✓)
	Horseranch Range	C,M,W	AT, ESSF, BS	5,230 (✓,✓)
	Liard Plateau	C,W	AT, ESSF, BS	1,360 (✓,✓)
	MacDonald-Racing	C,W	AT, ESSF, BS	310 (✓,✓)
	Pink Mtn-Halfway	C,W	AT, ESSF, BS	1,000 (✓,✓)
	Prophet River	C,W	AT, ESSF, BS	4,610 (✓,✓)
	Toad River	C,W	AT, ESSF, BS	490 (✓,✓)

[1] C - caribou, M - moose, S - sheep, W - wolf

[2] AT - alpine tundra, ESSF - Engelmann spruce/subalpine fir
BS - boreal black and white spruce, SBS - sub-boreal spruce.

[3] (✓✓) - surveyed in 1978-79 and 79-80; ((✓) - surveyed in 1978-79; (✓) - surveyed in 1979-80

Table 2. Some ecological features of biogeoclimatic zones in the survey areas.

Feature	Zone			
	Alpine tundra	Engelmann spruce -subalpine fir	Sub-boreal spruce	Boreal white and black spruce
Elevational range (m)	915	915 - 2,300	335 - 855	170 - 855
Annual precip. (mm)	745	405 - 1,830	405 - 635	305 - 585
Annual snowfall (mm)	5,460	1,750 - 10,160	1,525 - 2,795	1,195 - 3,125
Mean monthly temp. (C)				
Jan.	-17	-18 to -7	-17.5 to -11.5	-24 to -14.5
July	11	8.5 to 15.5	13 to 15	12 to 16.5
Annual temp. range (C)	10.5	2.5 to 14.5	9 to 14	10 to 21
Climatic regime	subarctic	continental cold humid	sub-boreal (cold) continental humid	boreal (cold) continental humid
Forest cover	none	subalpine coniferous	sub-boreal coniferous	boreal (to sub-arctic coniferous
Plant indicators	moss leather cranberry pink mountain heather yellow mountain heather	subalpine fir heart leaved arnica single-flowered clintonia Engelmann spruce Rhytidiopsis robusta mountain bilberryaceum oval-leafed bluberry	subalpine fir paper birch Engelmann spruce white spruce black spruce lodgepole pine quaking apsen	paper birch Labrador tea white spruce black spruce lodgepole pine

CARIBOU

For caribou, most surveys were completed in October, with a few conducted in February. In 1978-79, a total of 4,789 caribou were counted on 19 survey units (Table 3). Estimated calf crops ranged from a low of 8% for the Axelgold-Sikanni herd to 36% for the Ilgachuz Range herd. In the following year, a total of 4,686 caribou were counted on 19 areas; some areas were different from 1978-79 (Table 4). Similar to the previous year's results, calf crops varied widely, from 6% at Lawyer's Pass to 21% at MacDonald-Racing (Table 5).

MOOSE

Unfavourable weather and snow conditions hampered surveys for most of the study areas. However, in the 1978-79 winter, 564 moose were classified on five survey areas while in the 1979-80 winter, 611 moose were classified on six areas (Tables 6 and 7). The proportions of calves on these surveys ranged from 9-28%.

On four survey areas, population estimates of moose were attempted based on a stratified random sampling system. Density estimates ranged from 0.23 to 1.33 moose/sq km (Table 8).

WOLVES

For wolves, most surveys were flown in winter when snow cover and conditions aided location of wolf packs. In the 1978-79 winter, a total of 12 survey areas or 28,720 sq km was searched, and the estimated number of wolves was 241 or 119 sq

Table 3. Classified counts of caribou surveyed during October 1978 - March 1979 in the wolf/ungulate project.

Region or subregion	Survey unit	Adults			Calves	Unclassified	Total counted
		males	females	u/c[1]			
Caribou	Itcha Mt.	18		99	66		183
	Ilgachuz Mt.	28		91	51		170
	Rainbow Mt.	6		20	11		37
Skeena	Atlin					454	454(5)[2]
	Kawdy/Jennings			143	40	217±	400
	Level Mt.			51	72	182	305(3)
	Mt. Edziza	1	5			37	43(2)
	Spatsizi			920	144	300	1364(7)
	Tweedsmuir Circle			60	17		77
Omineca	Axelgold-Sikanni			12	1		13
	Germansen Lake			7	1		8
	Lawyers Pass			442	51		493(2)
Peace-Liard	Cypress River			57	19		76
	Horseranch	42	182		44		268
	Liard Plateau			256	41		297
	MacDonald-Racing			9	4		13
	Pink Mt-Halfway			164	47		211
	Prophet River			163	56		219
	Toad River			49	9		58
Totals	19 areas	95	187	2543	674	1190	4689

[1] unclassified.
[2] no. of flights.

Table 4. Classified counts of caribou surveyed during October 1979 - March 1980 in the wolf/ungulate project.

Region or subregion	Survey unit	Adults			Calves	Unclassified	Total counted
		males	females	u/c[1]			
Caribou	Ilgachuz Mt. Itcha Mts.	82	32		10	385	509
Skeena	Atlin			168	34	89	291
	Kawdy/Jennings	68	189		64	216	537
	Level Mt.	89	348		35		472(2)[2]
	Little Rancheria	55	117		22		194
	Mt. Edziza			44	6		50(3)
	Spatsizi	125	362	237	79	2	805(5)
	Tweedsmuir Circle		12	9	2		23
Omineca	Germansen Lake			12	3		15
	Lawyers Pass			295	18		313(4)
Peace-Liard	Cypress River			109	22		131
	Gataga-Kechika			34	6		40
	Horseranch	44	198		41	5	288
	Liard Plateau			244	57		301
	MacDonald-Racing			53	14		67
	Pink Mt-Halfway			232	42		274
	Prophet River			99	16		115
	Toad River			219	42		261
Totals	19 areas	688	1258	1755	513	697	4686

[1] unclassified.
[2] no. of flights.

Table 5. Trends in proportions of calves in caribou herds, 1977-1980.

Region or sub-region	Survey unit	Percentage of calves (sample size) 1977-78[1]	1978-79	1979-80
Caribou	Itcha-Ilgachuz -Rainbow Mts	16(279)	33(390)	nc
Skeena	Atlin	15(250)[2]	nc[3]	17(202)
	Kawdy-Jennings	4(811)	22(183)	20(321)
	Level Mt.	3(434)	25(229)	9(286)
	Little Rancheria	2(500)	ns[3]	11(194)
	Mt. Edziza	0(37)	nc[3]	12(50)
	Spatsizi		14(1064)	10(805)
	Tweedsmuir Circle	17(75)[2]	22(77)	ss[3]
Omineca	Axelgold-Sikanni	ns[3]	ss[3]	nc[3]
	Germansen Lake	22(100)	ss[3]	20(15)
	Lawyers Pass	10(1050)	10(493)	6(313)
Peace -Liard	Cypress River	16(125)[2]	25(76)	17(131)
	Gataga-Kechika	10(50)[2]	ns[3]	15(40)
	Horseranch Range	4(250)	16(268)	14(288)
	Liard Plateau	10(125)	14(297)	19(301)
	MacDonald-Racing	23(60)	ss[3]	21(67)
	Pink Mt.-Halfway	16(200)	22(211)	15(274)
	Prophet River	16(75)	26(219)	14(115)
	Toad River	10(250)	16(58)	16(261)

1 taken from Bergerud (1978:89-90).
2 estimates based on tracks plus sightings.
3 ns-not surveyed, nc-not classified, ss-small sample.

Table 6. Classified counts of moose surveyed during October 1978 - March 1979 in the wolf/ungulate project.

Region or sub-region	Survey unit	Adults			Young of the year	Total counted
		males	females	u/c	no. (%)[1]	
Skeena	Level Mt.	4	13	33[2]	15(23)	65
Omineca	Salmon-Willow	10	25		11(24)	46
	Stuart-Tezzeron	21	56		21(21)	98
Peace -Liard	Cameron-Chowade	62	128		59(24)	249
	Horseranch	11	10		2(9)	23

[1] based on proportion of classified moose.
[2] adults not classified as to sex.

Table 7. Classified counts of moose surveyed during October 1979 - March 1980 in the wolf-ungulate project.

Region or sub-region	Survey unit	Adults			Young of the year	Total counted
		males	females	u/c	no. (%)[1]	
Skeena	Level Mt.	not available				
Omineca	Salmon-Willow	23	56		30(28)	109
	Stuart-Tezzeron	19	37		4(7)	60
Peace -Liard	Beatton-Blueberry	33	89		27(18)	149
	Cameron-Chowade	45	131		46(21)	222
	Horseranch	11	16		4(13)	31

[1] based on proportion of classified moose.
[2] adults not classified as to sex.

Table 8. Estimated densities of moose made during the 1978-79 and 1979-80 winters in the wolf/ungulate project.

Region or sub-region	Survey unit name	Survey unit area	Moose density per km² 1978-79	Moose density per km² 1979-80
Skeena	Level Mt	4560 km²	0.34 ±0.12	0.24 ±0.14
Peace -Liard	Beatton-Blueberry	4480 km²	ns[1]	0.70
	Cameron-Chowade	4950 km²	1.33	ns[1]
	Horseranch	360 km²	0.30 ±0.23	0.48 ±0.34

[1] not surveyed.

Table 9. Estimated wolf densities made during the 1978-79 winter in the wolf/ ungulate project.

Region or subregion	Survey unit	Area (km²)	Estimated no. of wolves (no. packs)	Density wolves per 100 km²	Density km² per wolf
Caribou	Itcha-Ilgachuz	3760	7(2)	0.2	540
Skeena	Atlin	1770	13	0.7	140
	Level Mt	4510	40(6-7)	0.9	105
	Spatsizi[1]	1480	62-67	4.2-4.5	22-24
Peace	Horseranch	3620	29(3)	0.8	125
	Liard Plateau	1360	4(1)	0.3	340
	MacDonald-Racing	1760	9(3)	0.5	195
	Toad River	490	3(1)	0.6	163
	Cypress River, Cameron Chowade, Prophet River, Pink Mt.-Halfway	9970	71(12)	0.7	140
All areas		28720	238-243(28-29)	0.8	119

[1] based on two flights.

Table 10. Estimated wolf densities made during the 1979-80 winter in the wolf/ungulate project.

Region or subregion	Survey unit	Area (km^2)	Estimated no. of wolves (no. packs)	Density: wolves per 100 km^2	Density: km^2 per wolf
Skeena	Level Mt	6270	54-56(7)	0.7	131
	Spatsizi	1370	7(1)	0.5	196
Peace -Liard	Liard Plateau	1890	10(2)	0.5	190
	Horseranch	5230	27(4)	0.5	194
	Cypress River, Cameron-Chowade				
	Prophet River, Pink Mt.-Halfway	9970	83(13)	0.8	120
	Gataga-Kechika, MacDonald-Racing, Toad River	13780	75-78(15)	0.6	163
All areas		38510	259(42)	0.7	149

km/wolf (Table 9). Average pack size was approximately eight wolves, based on an estimated 28-29 packs recorded. In the 1979-80 winter, a total of 11 survey areas or 38,510 sq km was searched, and the estimated number of wolves was 259 or 149 sq km/wolf (Table 10). An estimated 42 packs were encountered with an average pack size of six.

DISCUSSION

RECRUITMENT AND WOLF PREDATION

The historical status of caribou in British Columbia has been summarized by Bergerud (1978). His report highlighted the fact that recently many herds have had very low recruitment of yearlings, especially for the 1977 to 1978 annual cycle. He further noted that in many cases, wolf densities probably exceeded one per 130 to 156 sq km; a density above which he felt wolves could have a serious impact on their prey populations, particularly caribou, and presumably for "average" densities of prey. It can be seen from the work reported here that a number of areas have densities of that magnitude, with most northern areas being within the range of one wolf per 112 to 196 sq km (Tables 9 and 10). These densities represent an estimated annual food consumption by wolves of 7 to 14 kg/sq km, assuming that an average wolf eats about 1400 kg of meat annually (Mech 1970).

However, the interdependence of wolf numbers and ungulate numbers is far from simple. Bergerud (1978) indicates an average density on the northern ranges of 0.04 to 0.08 caribou per sq km. If wolves were to eat solely caribou, they could remove the entire population in less than a year. They would of course starve prior to reaching this end: incidental observations during field work for this study indicated that at least winter feeding was primarily upon moose. Many other studies of northern areas support the importance of moose in the winter diet of wolves (Fuller and Keith 1980, Jordon et al. 1971, Peterson 1977, Pimlott et al. 1969).

Measured moose densities (Table 8) convert to a standing crop on the order of 80 to 480 kilograms per sq km. Average wolf numbers would not make inroads on the standing crop for these densities at the moose recruitments reported here, although little surplus for population growth (or hunter harvest) would exist.

Recruitment, however, is the key to the whole interaction and is far and away the most complex aspect. A number of variables is involved: density of wolves (DW), density of prey juveniles (DP), dispersion of prey juveniles (AP), and search selectivity of wolves for that prey (SP). For a limited range of the variables, the number (N) of juveniles captured for a given time can probably be assumed linear:

$$N \propto DW \cdot DP \cdot AP \cdot SP$$

The density of the prey juveniles is in turn directly related to the prey density of all age groups or the total prey numbers (PN) per the range area (RA):

$$N \propto DW \cdot AP \cdot SP \cdot PN/RA$$

If the dispersion, search selectivity, and range areas are randomized then,

$$N \propto DW \cdot PN$$

or

$$N = c + d \cdot DW \cdot PN \qquad (1)$$

where c and d are constants. The number of juveniles captured (N) is also derivable from the recruitment (R):

$$N = PN\ (e\text{-}R) \qquad (2)$$

where e is the proportion of the total animals producing calves. Combining equations (1) and (2) yields:

$$PN\ (e-R) = c + d \cdot DW \cdot PN$$

Thus,
$$e-R = c + d \cdot DW$$

or,
$$R = b \cdot DW + a \qquad (3)$$

where $b = -d$

and $a = e - c$

Equation (3) can be examined with the present data to yield constants for caribou. Due to the proportional nature of recruitment data, it must first be converted with the angular transformation in order to reduce playkurtosis and the tendency of the variance to depend upon the mean. Incorporating this feature the best fit regression is:

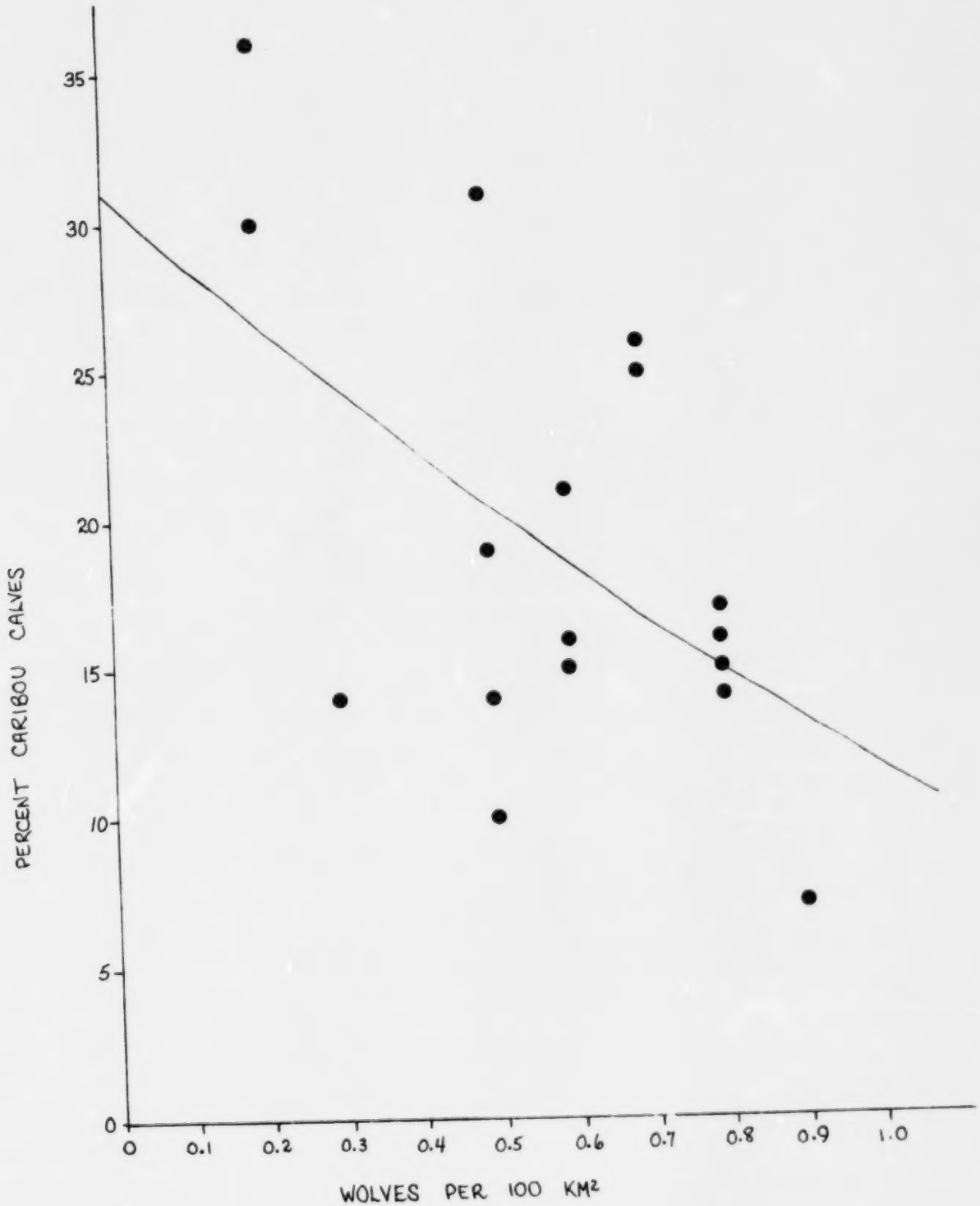
$$Z = 33.9 - 13.9\ W \qquad (4)$$

where W is the number of wolves per 100 square kilometers and Z is the number of degrees of the angular transformation of winter calf caribou recruitment.

The data plus the best fit regression are shown on Figure 2.

An analysis of variance (Appendix C) indicates that a significant (probability of arising by chance less than 10%) portion of the variation of caribou recruitment estimates (38%) was removed by the regression of equation 4. It was expected that a masking of the predator effect - increasing variability - was resulting from a differential prey biomass masking. This feature could not be analyzed parametrically due to a limited data base. In consequence, the total prey biomass for each caribou area known to the author was given a rating and compared to the positive deviation of recruitment from the regression of equation (4) using Kendall's coefficient of rank correlation (Appendix C). The probability of the

Figure 2. DEPENDENCE OF WINTER CARIBOU RECRUITMENT UPON WOLF DENSITY



degree of correlation found occurring by chance (that is not correlated) was found to be 0.124. It appears, in an analogy, to paramatric techniques, that about 8% of the deviations from the regression of equation 4 are explicable by a prey biomass effect on predation. This increases the portion of explicable variation in caribou recruitment resulting from wolf numbers to about 46%.

The identification of this relation between caribou recruitment and wolf numbers lends considerable credence to the hypothesis that wolf predation controls caribou numbers. Indeed, utilizing Bergerud's (1978) formula relating mortality of non-calf caribou to calf recruitment and including one to two percent further loss to yearling age, one would expect unhunted caribou herds to decline where wolf densities exceed 1 wolf per 100 sq km.

Average wolf densities recorded (0.7 to 0.8 per 100 sq km) generally will result in winter recruitment of about 15% (Equation 4). Again, utilizing Bergerud's (1978) formula and assuming a one percent further decline until June, the herds should be increasing (in the absence of hunting mortality) at the rate of 5-6% per year. Unfortunately, the margin of error in inventory is greater than 5-6% so that population changes cannot be confirmed when comparing herds over only twelve months. There are only three sizable herds for which there are population estimates over a longer time period: Toad River with a 4-5% annual increase for the past four years, Horseranch where wolves were reduced with a 7% annual increase over the last four years and Liard with a 1-2% annual decline for the period 1975-1979. All of these herds are hunted.

A comparison between moose recruitment and wolf density (Fig. 3) is limited by the small data base. However, for survey areas where data are available for two

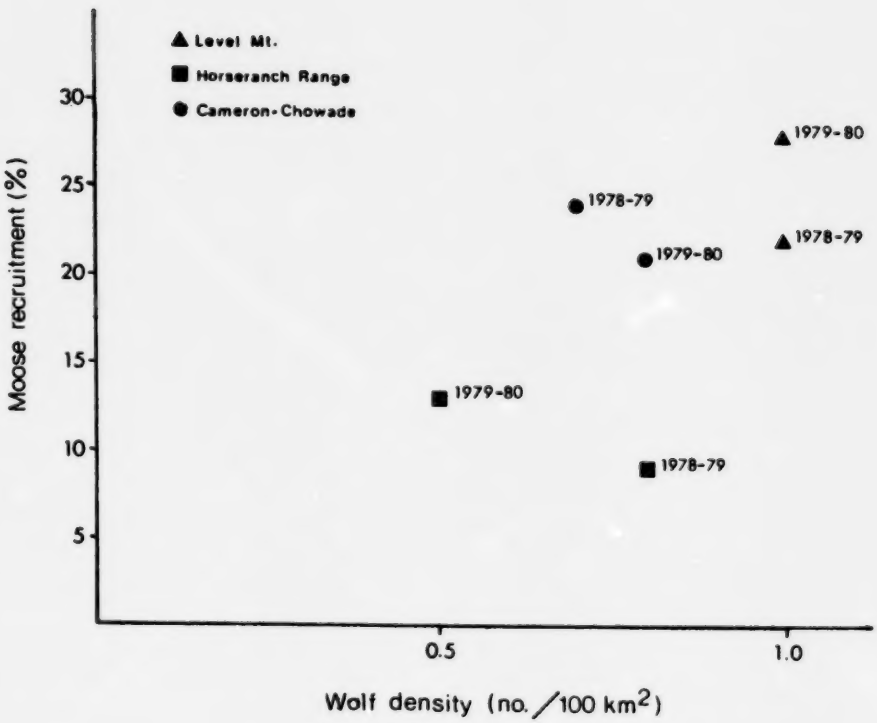


Fig. 3. Late winter moose recruitment relative to wolf numbers.

years where habitat was unchanged but wolf densities changed - the recruitment of moose dropped as wolf density increased. Furthermore, the trend over time of wolf numbers was reversed for the two areas, which tends to eliminate any weather effect on food. Statistical examination of the data is not possible for only two data sets. It should, of course, be noted that the "food effect" has a very high magnitude. This supports the hypothesis that wolf predation controls moose numbers. A comparison of the three areas shows high variability but no trend. Data reported by Elliott and Webster (1982) for more sample areas and years showed reduced recruitment for moose as wolf density increased.

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Appendix A. Common and scientific names of animals and plants mentioned in the text.

Scientific Name	Common name
ANIMALS [1]	
Alces alces	moose
Canis lupus	wolf
Ovis dalli	Stone sheep
Rangifer tarandus	caribou
TREES AND SHRUBS [2]	
Abies lasiocarpa	alpine fir
Betula papyrifera	paper birch
Cassiope mertensiana	moss heather
Empetrum nigrum	crowberry
Ledum groenlandicum	Labrador tea
Phyllodoce empetriformis	pink mountain heather
Phyllodoce glandulifera	yellow mountain heather
Picea engelmannii	Engelmann spruce
Picea glauca	white spruce
Picea mariana	black spruce
Pinus contorta	lodgepole pine
Populus tremuloides	quaking aspen
Vaccinium membranaceum	mountain bilberry
Vaccinium ovaliforium	oval-leafed blueberry
FORBS	
Arnica cordifolia	heart-leaved arnica
Clintonia uniflora	single-flowered clintonia
MOSSES [3]	
Rhytidiopsis robusta	

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[1] nomenclature based on Banfield (1974).

[2] nomenclature based on Hitchcock et al. (1969).

[3] nomenclature based on Schofield (1969).

APPENDIX B. Maps and descriptions of survey units.

This section presents descriptions of the survey areas or units with respect to their rationale for selection, location, plane area, boundaries, elevational range, and general ecological feature. The survey units are presented alphabetically within each region and subregion from Region 5 to Region 7. Descriptions of boundaries employ place names and geographic features named on 1:250,000 maps.

REGION 5: CHILCOTIN-CARIBOU

Ilgachuz-Itcha-Rainbow Survey Units

These three areas are described together because of their proximity and similarity to one another. Caribou and wolves were the key species for these survey areas. Traditionally, caribou rut on one or more of the three apline platueas found in the Ilgachuz, Itcha and Rainbow ranges. In previous surveys, only one or two of these plateau were flown. Thus a total estimate of herd size was not possible since caribou probably move between these areas. Furthermore, Bergerud noted information on wolf densities was almost non-existent.

This survey area occupies about 5,850 km^2 on the Fraser Plateau, about 200 km west of Williams Lake (Fig. B1). It is located on the Anahim Lake (93C) and Bella Coola (93D) map-sheets and is contained within Management Units 5-6, 5-10, 5-11 and 5-12.

The area is bounded in the east by a line from Redtop Mountain at the confluence of the Chilcotin and Clusko Rivers about 140 km due west of Williams Lake, north over the swampy low area of Moore Creek to the west of Thunder Mountain, crossing the Baezaeko River to the east of North Hill. Turning west at Bishop Bluss (the northeast corner), the line heads roughly south of west over the lake draining into the West Road (Blackwater) River, then continues west-southwest across the Dean River to the north of the Rainbow Range where it intersects the Tweedsmuir Park boundary; southwest of Squiness and Tanya Lakes, down the Takia River and south up the Tahyesco to a point just northwest of Tine Hill. The southern edge of the area runs east, through the "valley" over the headwaters of Young Creek, crossing Highway 20 twice and down a small creek flowing into the Dean River just at its outlet at Abuntlet Lake, then east to Redtop Mountain.

More than half of this area, the land above approximately 1,200 m, is in the subalpine fir and Engelmann spruce biogeoclimatic zone. The Upper chilcotin valley in the southeast corner, and the valley of the Dean River are sub-boreal spruce zone. The highest peaks, above 1,520 m, are alpine tundra.

REGION 6: SKEENA

Atlin Survey Unit

This area, in the northwest corner of the province (Fig. B2), was selected to gain information on caribou; earlier data were scanty and the level of harvest had

been increasing. The general boundaries of the area extend southwards from the British Columbia - Yukon border along the eastern shore of Atlin Lake, then head eastward along the Sloka and Nakina River to the Teslin River, then northward on the Teslin river and western shore of Teslin Lake, and then westward along the British Columbia - Yukon border. Within this general area, surveys were conducted on the alpine habitats that occur on all the major mountain ranges. Caribou congregate to breed on these alpine areas in late September and October, the time of most surveys. The combined plane area of these rutting grounds was 1,770 km^2.

The lower elevations around Atlin Lake support boreal white and black spruce forests; slightly higher, and containing the larger valleys draining the plateaus are Engelmann spruce - subalpine fir forests; and the plateaus themselves, comprising virtually all of the plane area, are alpine tundra.

Mt. Edziza Survey Unit

This unit follows the boundaries of Mt. Edziza Provincial park, 100 km southwest of Dease Lake (Fig. B2). Covering an area of approximately 1,400 km^2, it consists primarily of the alpine tundra and Engelmann spruce - subalpine fir biogeocliamtic zones. The main reason for surveying this unit was to census the small herd of caribou whose status was of concern.

Kawdy-Jennings Survey Unit

This unit was surveyed for its large caribou herd, which numbers approximately 800 (Bergerud, 1977). It covers 1,310 km and occupies the Kawdy Plateau, 100 km west of Cassiar in the Cassiar Mountain (Fig. B2). The survey area extends from Kawdy Mountain on its southern edge north to, and across, the Jennings River. The plateau is bounded by Tuya Lake and River on the east, and by the Atsutla Range and the upper Teslin River on the west. The plateau is in alpine tundra, with deeper valleys and larger tributaries supporting subalpine forests of Engelmann spruce and subalpine fir. There is boreal white and black spruce around Teslin Lake.

Level Mountain Survey Unit

This unit includes the entire alpine area of the Level Mountain Range northwest of Dease Lake (Fig. B2). It was surveyed for caribou, moose and wolves. The unit comprises the undisturbed study area for the Wolf/Caribou project. (The project will be described in a subsequent report) Occupying 1,390 km^2, the Level Mountain unit lies to the north and northwest of the Stikine River valley, to the west of the Tuya River, and to the south of the headwaters of the Naklin River.

Ecologically, this survey unit is predominantly alpine tundra, with subalpine and boreal forests at middle and low elevations, respectively.

Little Rancheria Survey Unit

Caribou were the main reason for surveying this unit. The herd occupies the headwaters of Toozaza Creek and Little Rancheria River to the northeast of the Stikine Ranges of the Cassiar Mountains, east of Jennings Lake on the alpine areas above 1,220 - 1,370 m (Fig. B2). The rutting grounds are bounded on the north by Tootsee Lake and River, and the lower lands to the east and northeast. The Kawdy Plateau supports alpine tundra at higher elevations and subalpine Engelmann spruce - subalpine fir in the larger valleys; boreal black and white spruce occupy parts of the Blue River valley and the lower Little Rancheria running into the Yukon.

Spatsizi Survey Unit

This unit is bisected by the Stikine River and its larger tributaries, notably the Spatsizi (Fig. B4). Two major herds use this area; one group ruts on Caribou Mountain, the second on Mount Tomias. The former rutting ground is almost encircled by the Spatsizi River on the south, the Stikine on its east and north edges, and Cullivan Creek and Coldfish Lake on the southwest. Mount Tomias lies to the southeast of Caribou Mountain and is bounded by the Ross River to the west and the Stikine to the south, east and north. A ridge connects this part of the plateau with other caribou grounds on other peaks to the southwest. There is a little of the boreal spruce biogeoclimatic zone in the bottom of the Spatsizi and Stikine valleys, and a thin contour layer of subalpine spruce and fir at a slightly higher elevation. The greatest proportion of the 1,370 km^2 is alpine tundra. Pojar (1976) provides detailed ecological descriptions of a small part of the unit.

Tweedsmuir Circle Survey Unit

The caribou herds use the land encircled by Ootsa, Whitesail, Eutsuk, Tetachuck and Natalkuz Lakes on the Nechako Plateau, 160 km west of Prince George (Fig. B1). The Circle, containing a handful of alpine tundra patches, has a plane area of 4,300 km^2. The majority of the higher levels are subalpine Engelmann spruce-subalpine fir forests, while the lower elevations abutting the lakes and major rivers support the sub-boreal spruce.

REGION 7: OMINECA-PEACE

Axelgold-Sikanni Survey Unit

Surveyed only in the fall of 1978 and winter of 1979, the Axelgold and Sikanni ranges lie beside the headwaters and upper reaches of the Omineca River within the Stikine Mountains (Fig. B3). The combined area is 1,010 km^2. The Omineca and its larger tributary river valleys enclosing the two ranges are in the sub-boreal spruce biogeoclimatic zone, while the higher ground above the valleys are in subalpine Engelmann spruce and subalpine fir. The highest elevations are alpine tundra.

Germansen Lake Survey unit

Caribou occupy various parts of the Swannell and Hogem ranges of the Omineca Mountains, Mount Germansen lies between the Omineca River to the north and the Nation Lakes to the south (Fig. B3). Caribou inhabit the Mitchell Range and the Plughat Mountains. The Mitchell Ranges is 60 km southwest of the Germansen Range on the east side of Takla Lake. Plughat Mountain is north of Germansen lake. Th total area of this survey unit is 1,300 km^2. Elevations below 1,220 m support the sub-boreal spruce zone, common over the north central part of the British Columbia interior. The higher elevations are subalpine spruce and fir, with the peaks and ranges above 1,520 m in the alpine zone.

Lawyers Pass Survey Unit

The Lawyers Pass caribou occupy the part of the Spatsizi Plateau to the south of the upper reaches of the Stikine River, opposite Tomias Mountain (Fig. B3, B4). The area is circumscribed by a rough square whose sides run from Caribou Hide at the confluence of the Stikine and Moyez Creek, to the west end of Kitchener Lake, east to the north end of Thutade Lake; from there the eastern side runs north to Mulvany Lake, with the northern side back to Caribou Hide. The plane area is 1,960 km^2. In the Pass proper, and at the headwaters of Chappelle, Jellicoe and Lawyers Creeks, are Engelmann spruce - subalpine fir forests, while "fingers" of boreal spruce extend up the bottoms of the Sturdee and Firesteel Rivers to the south, and into the Toodoggone valley to the north of the Pass. Surrounding peaks, from 1,370 m up, are alpine tundra.

Salmon-Willow Survey Unit

This area is surveyed primarily for moose. Generally, it occupies the Salmon and Willow River valleys east and north of Prince George (Fig. B1). A line between Mount George and Spring Mountain forms the southeast boundary, and the area occupies a strip 15-25 km wide and 100 km long, downstream along the Willow River and upstream on the Salmon River to about Merton Hill. All of the 1,350 km^2 area lies within the sub-boreal spruce zone except the two more mountainous south-eastern corners, which are in the Engelmann spruce - subalpine fir zone.

Stuart-Tezzeron Survey Unit

The trapezoid-shaped area is 2,790 km^2, lying on the Nechako Plateau to the northwest of Prince George (Fig. B1). The boundaries encompass Great Beaver, Pinchi, and Tezzeron Lakes, and the eastern half of Stuart Lake. All of it lies within the sub-boreal spruce zone of the north-central interior.

Beatton-Blueberry Survey Unit

The moose in Beatton-Blueberry were surveyed for density in an area of 4,480 km^2 (Fig. B3). The Alaska Highway from mile 73 to mile 160 forms the southern and western boundary, the Beatton River logging road to just north of that river forms the eastern boundary, and the Sikanni Chief River forms the northern one. The whole area is at an elevation of approximately 900 m and is in the boreal black and white spruce zone.

Cameron-Chowade Survey Unit

A large area of 4,950 km^2 surveyed primarily for moose and wolves on the east slope of the Continental Divide due north of the Peace Reach of the Williston Reservoir (Fig. B3). It comprises parts of the drainages of the Chowade, Cypress, Halfway and Sikanni Chief Rivers, the last (with Sidenius Creek) forming the northern boundary. The area was surveyed to the Alaska Highway (mile 130 to mile 160) and to a line from mile 130 south to the head of Aikman Creek, on the east, and north of an east-west line from that point to the upper Graham River where it is joined by Horn Creek. The Cameron River is within the huge boreal black and white spruce zone east of the Halfway River. Higher land above the valleys and to the west of the Halfway is subalpine fir and spruce.

Cypress River Survey Unit

This is a caribou survey area. It runs into the Halfway River near mile 130 of the Alaska Highway (Fig. B3). It runs parallel to, and north of, the Chowade and Graham Rivers. All three drain the east slopes of the Muskwa Ranges of the Rocky Mountains on the Continental Divide, north of the Peace Reach of Williston Lake. The area used by caribou is approximately 570 km^2 and lies between the Cypress River, and the Halfway to the north, above 1,350 m. The deeper valley bottoms lie in boreal spruce forest as they run down from the Divide into the flatter lands of the Peace River region. Intermediate elevations support subalpine species, and only the peaks here are alpine tundra.

Gatage-Kechika Survey Unit

This unit is one of the largest survey areas (5,670 km^2), and lies in the troughs between the Kechika and Muskwa ranges about 225 km west-southwest of Fort Nelson (Fig. B4). It encloses the land from about 15 km down the Kechika River from the junction with the Gataga, and within lines 8-15 km to the west of the Kechika running southeast around its headwaters to Weissner Lake, and 8-15 km east of the Gataga River passing southeast by its headwaters to just north of Kwadacha Wilderness Park. Weissner Creek forms the approximate southeast boundary.

Horseranch Range Survey Unit

This unit sits on a north-northwest - south-southeast axis roughly parallel to, and east of, the meanderings of the Dease River, 60 km upstream from the town of Lower Post (Fig. B4). The range is approximately 42 km long and 11 km wide above the 1,220 m elevation contour. It is bounded on the south by the Rapid River and Looncry Lake, and on the east and north by swampy ground and lakes draining into the Red and Dease Rivers. The area of the range above 1,220 m is 360 km^2. The range is alpine tundra above 1,220 m. Looncry Lake at about 1,000 m lies in subalpine zone, while the Dease and Rapid River valleys and extensive land to the north are boreal forest.

Liard Plateau Survey Unit

The caribou herd in this unit uses the Caribou Range, 80 km north-northeast

of Muncho Lake and 48 km northwest of the Toad-Liard Rivere conlfuence (Fig. B4). The elevation of the plateau in this area is between approximately 600 m in the river valleys and 1,200 m at the peaks, and its plane area 960 km^2. The great majority of the plateau is subalpine forest, but in the valleys of the larger rivers and tributaries, i.e., the Grayling and Liard Rivers and Moule, Chalford, Vizer and Stanner Creeks, is boreal black and white spruce. One height of land near 2,000 m is in tundra.

MacDonald-Racing River Survey Unit

The caribou in this unit use the land encompasses by the convergence of the Racing and MacDonald Rivers in the Muskwa Ranges of the Rocky Mountains, between Stone Mountain and Muncho Lake parks against the Alaska Highway (Fig. B4). The southern boundary of the area runs along the west boundary of Stone Mountain Provincial Park to a point opposite the Wokkpash River, where it turns west and follows this river into the Racing. The wide valleys of the Racing, and the MacDonald, are in the boreal spruce biogeoclimatic zone with the higher ground between in the subalpine. There is one patch of sub-boreal spruce on Rhododendron Creek. The plane area is 310 km^2.

Pink-Mountain-Halfway River Survey Unit

Pink Mountain lies to the west of the Alaska Highway, at about mile 150, between the Highway and Sikanni Chief Rivers (Fig. B3). The caribou use an area of 1,000 km^2 in the high lands above 1,500 m enclosed by the Halfway, the Sikanni Chief, and Sidenius Creek. Most of the area is sub-alpine, intermediate in elevation between the Continental Divide and the huge boreal forests of the northeast corner of British Columbia. Occasional peaks are in alpine tundra. Much of the valley bottoms support the boreal spruce zone; Marion and Lily Lakes straddle the edge of the boreal spruce zone proper.

Prophet River Survey Unit

The area of 4,610 km^2 surveyed as the Prophet was taken as that area enclosed within the Alaska Highway from the Trutch settlement (mile 200) to the village of Sikanni Chief (mile 160), the Sikanni Chief River on the south, the Continental Divide on the Wahthinli River on the east, and a line due east to Trutch as the northern boundary (Fig. B3, B4). Ecologically, the unit is generally the same as the Prophet but at a slightly higher elevation.

Toad River Survey Unit

Caribou in this area of 1,100 km^2 use the Muskwa Ranges just to the south of Muncho Lake Provincial Park and east of the Toad to the Racing River (Fig. B4). The biogeoclimatic habitat associations are characteristic of northern British Columbia with boreal black and white spruce forests in the larger river valleys, subalpine Engelmann spruce or fir at intermediate elevations, and tundra on the peaks and plateaus above about 2,000 m.

Fig. B1. Location of survey areas Ilgachuz Range, Itcha Range, Rainbow Range, Salmon-Willow, Stuart-Tezzeron, and Tweedsmuir Circle.

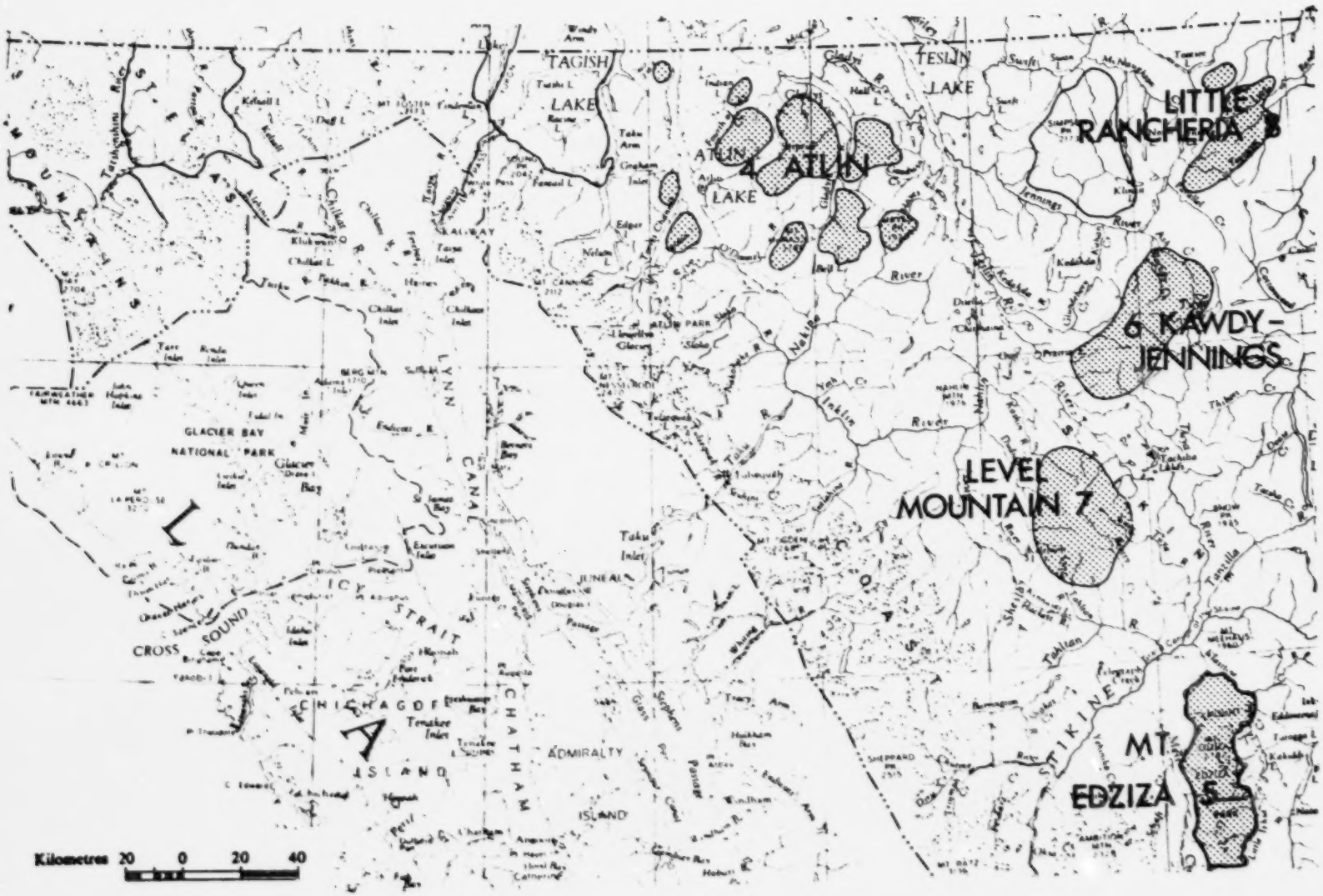

Fig. B2. Locations of survey areas Atlin, Kawdy-Jennings, Level Mtn., and Little Rancheria.

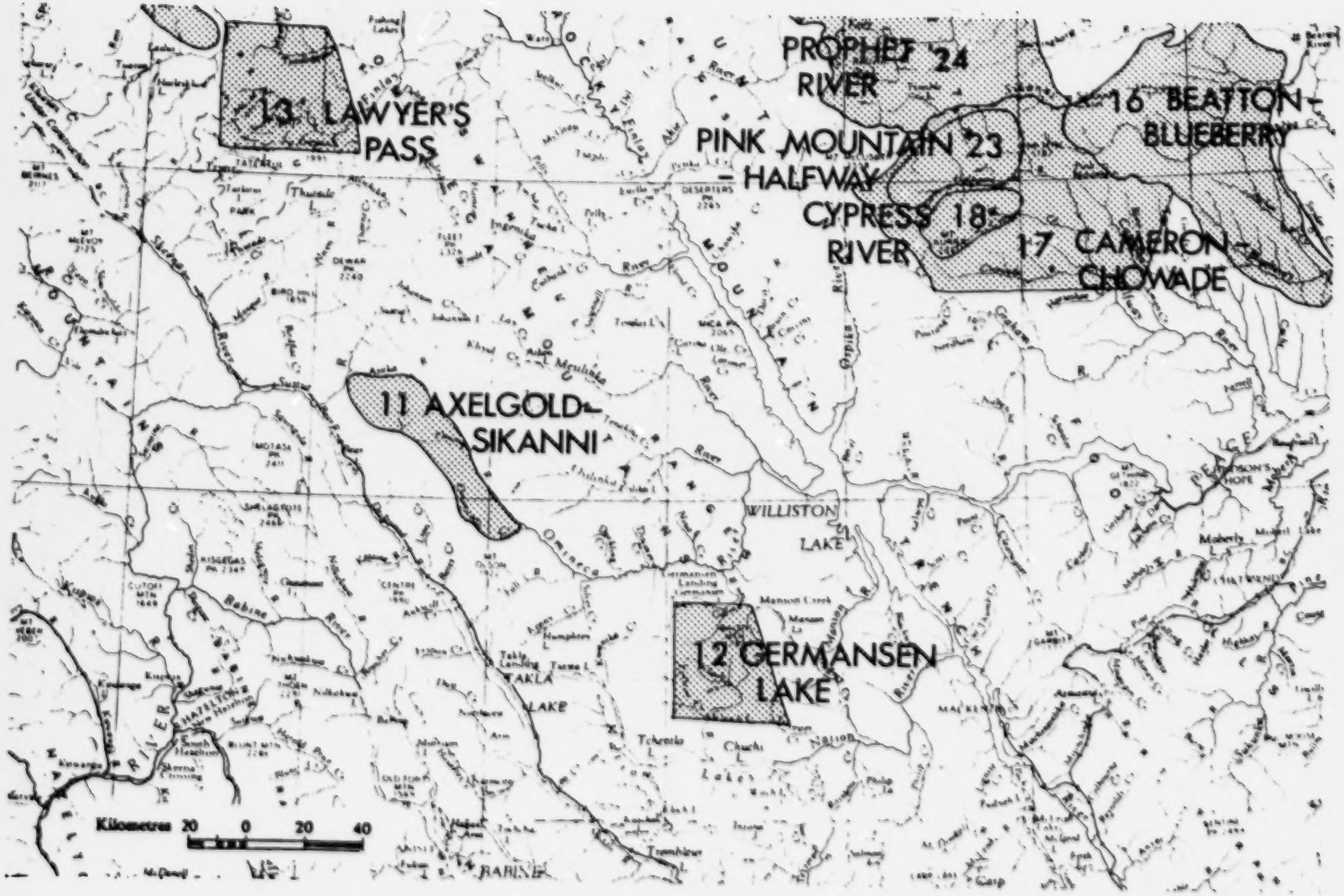

Fig. B3. Locations of survey areas Axelgold-Sikanni, Beatton-Blueberry, Cameron-Chowade, Cypress Creek, Germansen Lake, Lawyer's Pass, Pink Mountain-Halfway, and Prophet River.

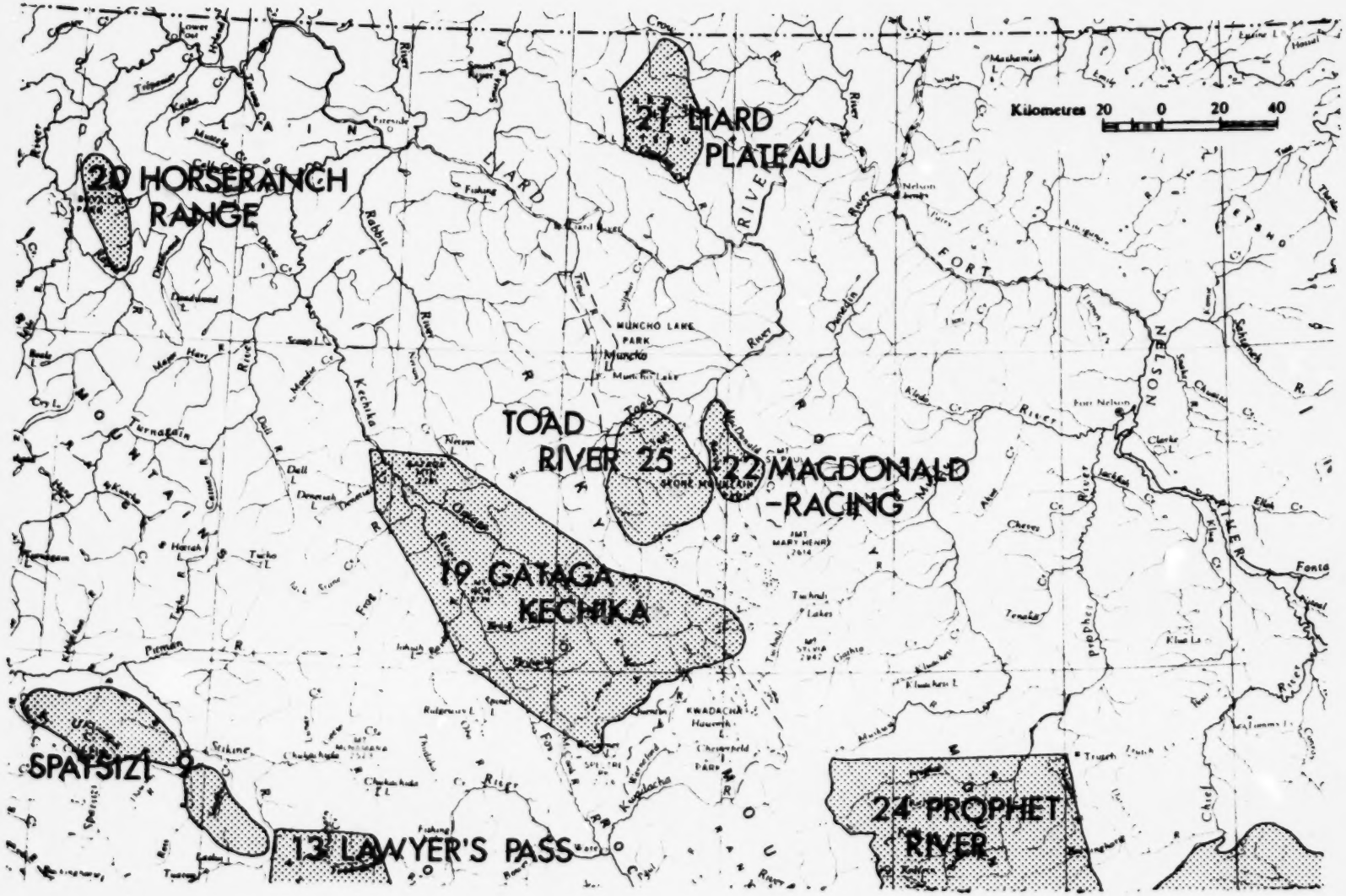

Fig. B4. Location of survey areas Gataga-Kechika, Horseranch Range, Lawyers Pass, Liard Plateau, MacDonald-Racing, Prophet River, Spatsizi, and Toad River.

APPENDIX C. Results of statistical analyses.

Table C-1 Analysis of variance, number of degrees (angular transformation) of caribou calf recruitment regressed against the number of wolves per 100 sq. km.

Source of variance	Degrees of freedom	Sums of squares	Mean squares	F	P<
Y - Y among groups	7	374.33	53.48	5.123	.01
Y - Y linear regression	1	140.48	140.48	3.604	.10
Y - Y deviations from regressions	6	233.85	38.98	3.733	.20
Y - Y within groups	12	125.30	10.44		
Y - Y total	26	499.63			

Table C-2 Kendall coefficient of rank correlation: total prey biomass (rank) contrasted with the proportion of reduced wolf impact (rank) relative to that predicted by equation 2 for caribou (only for areas known by authors).

Area, year	Rank (low to high)	
	Reduction of wolf impact	Total prey biomass
Level, 1980	1	1
Liard, 1979	2	9.5
Horseranch, 1980	3	6.5
Gataga, 1980	4	8
Toad, 1979	5.5	4.5
Toad, 1980	5.5	4.5
Liard, 1980	7	9.5
Prophet, 1980	8	11.5
Pink Mountain/Halfway, 1980	9	15.5
Horseranch, 1979	10	6.5
MacDonald/Racing, 1980	11	2.5
Cypress, 1980	12	13.5
Pink Mt./Halfway, 1980	13	15.5
Cypress, 1979	14	13.5
MacDonald/Racing, 1979	15	2.5
Prophet, 1979	16	11.5

Coefficient = 0.2846, t - 1.5376, p = 0.124.